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THE UNIVERSITY OF TENNESSEE
DEPARTMENT OF ELECTRICAL ENGINEERING

DEVELOPMENT

OF A

HIGH FREQUENCY

STEERABLE ANTENNA

Navy Department
Bureau of Ships
Electronics Divisions

Interim Development
Report No. 14

Contract No. NObsr-57448
Index No. NE-091035 ST7
10 November 1953

A PROJECT OF THE ENGINEERING EXPERIMENT STATION
THE UNIVERSITY OF TENNESSEE COLLEGE OF ENGINEERING
Knoxville 16, Tennessee

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INTERIM DEVELOPMENT REPORT

FOR

DEVELOPMENT OF A HIGH FREQUENCY STEERABLE ANTENNA

This report covers the period
1 October 1953 to 31 October 1953

ENGINEERING EXPERIMENT STATION
THE UNIVERSITY OF TENNESSEE
KNOXVILLE, TENNESSEE

Navy Department — Bureau of Ships
Electronics Divisions

Contract No. NObsr-57448 — Index No. NE-091035 ST7

10 November 1953

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ABSTRACT

This report covers work done on Contract No. NObsr-57448, Index No. NE-091035 ST7, at The University of Tennessee during the month of October 1953.

The following was accomplished:

1. The antenna pattern recorder was installed.

2. The calculations of antenna patterns of an inclined-V antenna were completed.

3. Work was continued on experimentally determining the correct termination to be used on the 1200 Mc model of the circular traveling-wave antenna in order to satisfactorily reduce standing waves on the antenna.

4. The investigation of the possibility of accomplishing vertical steering of the antenna beam by using two rhombics stacked vertically was continued.

5. An expression was derived for the radiation pattern of a vertical half-rhombic mounted over an earth of finite conductivity.

PART I

Purpose

This project involves the development of a high frequency steerable antenna having the following characteristics:

1. It shall be operable throughout the frequency range of 4 to 32 megacycles per second.

2. It shall be capable of four, or more, simultaneous transmissions on different frequencies, and at different azimuth and elevation angles.

3. For each transmission, it shall be capable of being directed to any azimuth angle and to any elevation angle between the horizon and 30^{o} above the horizon.

The communication system shall provide reliable 24-hour day-to-day communication with a 20 decibel signal-to-noise ratio. The ranges to be covered are from approximately 500 nautical miles to 4000 nautical miles.

The development consists of two phases:

Phase I. Theoretical and experimental studies.

Phase II. Development of design criteria.

General Factual Data

Personnel:

F. V. Schultz	Project Director	65	Man-hours
W. E. Lear	Associate Engineer	47 1/4	Man-hours
W. O. Leffell*	Assistant Engineer	20	Man-hours
W. J. Bergman	Junior Engineer	160	Man-hours
H. P. Neff	Junior Engineer	176	Man-hours
G. R. Turner	Secy-Draftsman	54	Man-hours
L. Phillips	Technician	68	Man-hours
W. H. Williams	Technician	16	Man-hours
R. Emmert	Student Computer	34 1/2	Man-hours
R. Johnson	Student Computer	11 1/2	Man-hours
H. Knox	Student Computer	72 1/2	Man-hours
L. Lay	Student Computer	7	Man-hours
W. Riggins	Student Computer	17 1/2	Man-hours
L. Childress	Multilith-Operator	2	Man-hours

* Preparation of antenna test facility.

References

Bruce, E. and Beck, A. C., "Experiments with Directivity Steering for Fading Reduction," Bell System Technical Journal, Vol. 14, p. 195, April 1935.

Foster, Donald, "Radiation from Rhombic Antennas," Proceedings of the Institute of Radio Engineers, Vol. 25, p. 1327, October 1937.

Hammond, P., "Power Gain of Curtain Arrays of Aerials" Wireless Engineer, Vol. 30, p. 108, May 1953.

Harper, A. E., Rhombic Antenna Design, D. Van Nostrand Co., Inc., New York, 1941.

Harrison, C. W., "Radiation from Vee Antennas," Proceedings of the Institute of Radio Engineers, Vol. 31, p. 362, July 1943.

Jordan, E. C., Electromagnetic Waves and Radiation Systems, Prentice Hall, Inc., New York, 1950.

Kraus, J. D., Antennas, McGraw-Hill Book Co., New York, 1950.

"New Configuration of Non Resonant Type Antenna," First Quarterly Progress Report, Andrew Alford, Consulting Engineers, July 1953.

Williams, H. P., Antenna Theory and Design, Pitman and Sons, Ltd., London, 1950.

Detail Factual Data

1. The antenna pattern recorder was installed and it is now operating satisfactorily. This completes the initial development of the antenna test facility; further work on the facility will be in the nature of refinements or modifications. Photographs of the installation will be included in the next interim report.

2. The limited investigation of inclined-V, or Maypole, antennas was completed. Calculations were made of the vertical pattern through the plane of symmetry of the antenna to show the variation in this pattern when one of the following three antenna parameters is varied and the other two are held constant: leg length (ℓ), height (h) and included angle (2τ). The results are shown in Figures 1 to 16, inclusive.

No further work is planned on this antenna type since it has been learned that another laboratory is investigating the antenna. The work herein reported, however, does not duplicate any work done by the other laboratory.

3. The experimental work of determining a correct termination for the circular traveling-wave antenna was continued. A frequency-sensitive termination was developed which resulted in a variation in current of only about plus or minus 1.5 db over the length of the antenna. This is approaching the limits of accuracy of the measurements and it is doubtful if the current distribution can be made more uniform. The relative current distribution on the antenna was determined by using a shielded loop. A dissipation line will now be constructed having a characteristic impedance as close as possible to the value of the above mentioned termination so that the antenna will be correctly terminated over a rather wide band of frequencies and radiation patterns can be determined over this frequency band.

4. The investigation of the possibility of accomplishing vertical steering of the antenna beam by using two rhombics stacked vertically was continued. By using two rhombics of the same size and shape, one above the other, it has been found possible, so far, to obtain only about ten degrees of steering without serious pattern deterioration. There are several variations yet to be investigated which may result in better performance in this regard.

5. An expression was derived for the radiation pattern of a vertical half-rhombic antenna mounted over an earth of finite conductivity. Calculations of a typical pattern are underway, but the expression is highly complicated so the calculations are long and involved.

Conclusions:

Figures 1 through 6 show the variation in the vertical pattern, through the plane of symmetry of the inclined-V antenna, as the antenna height (h) is increased from 0.125λ to 1.25λ, the leg length (ℓ) being held constant at 4λ and the half-included angle (τ) held at 25°. These curves show that the optimum height is about 0.731λ, for the particular values of ℓ and τ used, these in turn being approximately optimum values. Not much variation in h can be allowed without rather serious pattern deterioration.

Figures 7 through 12 illustrate the effect on the pattern of varying the half-included angle (τ), h and ℓ being held constant at their approximate optimum values. It is evident that the optimum value of τ is about 25°, for the constant values of ℓ and h used, but rather wide variations from this value of τ are allowable without much pattern deterioration. It is also noticeable that the larger values of τ result in the main lobe being at a slightly lower elevation angle.

The effect of varying ℓ, with h and τ being held at their approximately optimum values, can be seen from Figures 13 to 16, inclusive. These curves show that ℓ should be about 4λ, although a value of 6λ gives quite a satisfactory pattern. It is to be observed that as ℓ varies from 2λ to 8λ, the vertical angle of steering of the main beam goes from about 24° down to 12.5°.

DEPARTMENT OF ELECTRICAL ENGINEERING
ENGINEERING EXPERIMENT STATION
THE UNIVERSITY OF TENNESSEE

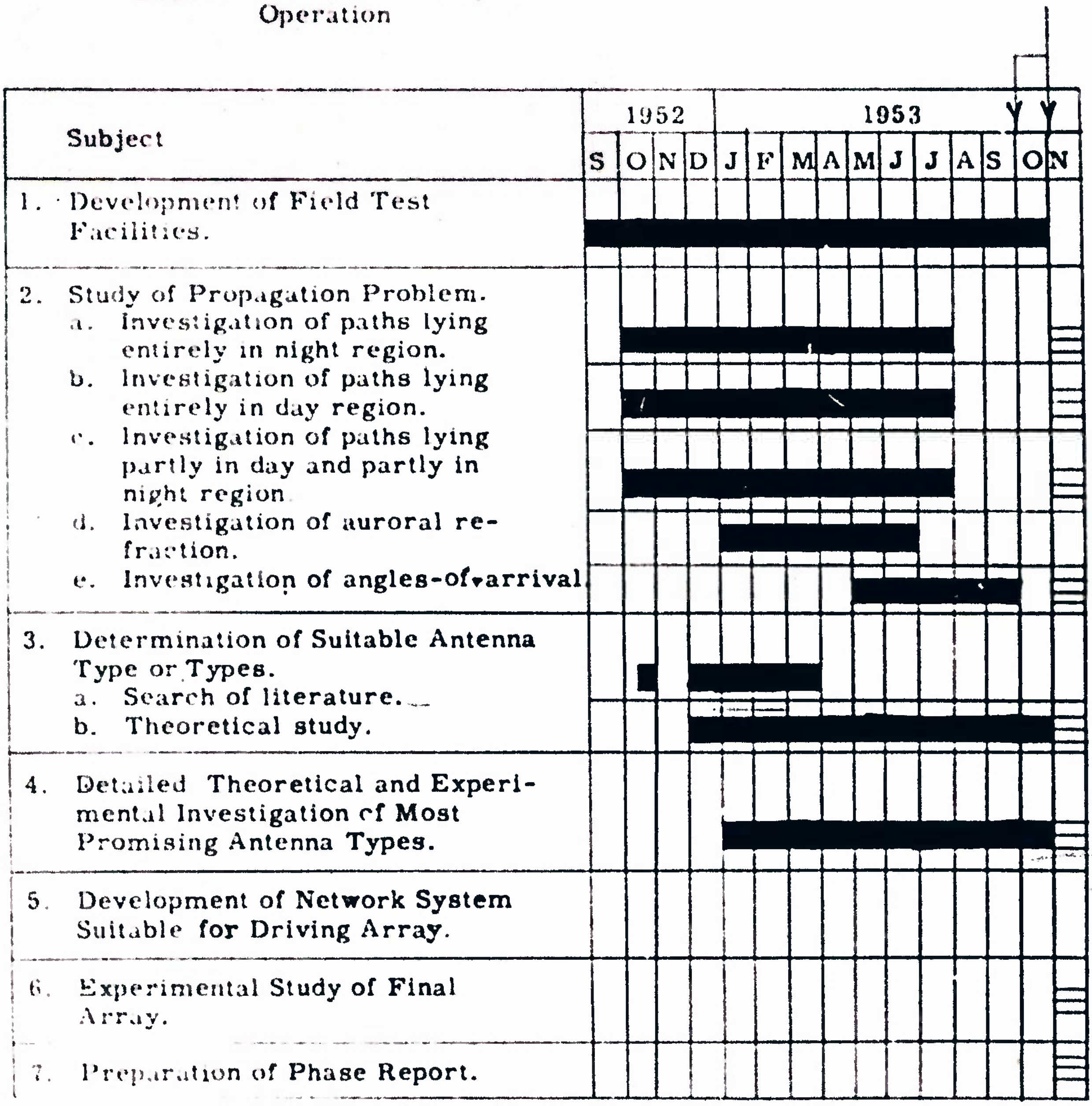
PROJECT PERFORMANCE AND SCHEDULE

Index No. NE-091035 ST7

Contract No. NObsr-57448 Date: 10 November 1953

Legend: Work Performed Period Covered: 1/10/53 to 31/10/53

Schedule of Projected Operation



PART II

Program for Next Interval

1. The task of correctly terminating the circular traveling-wave antenna will be continued. It is possible that pattern measurements will be made late in the month.

2. The investigation of the results achievable by the use of rhombics stacked vertically will be continued.

3. Calculations of a typical pattern of a vertical half-rhombic mounted over a earth of finite conductivity will continue.

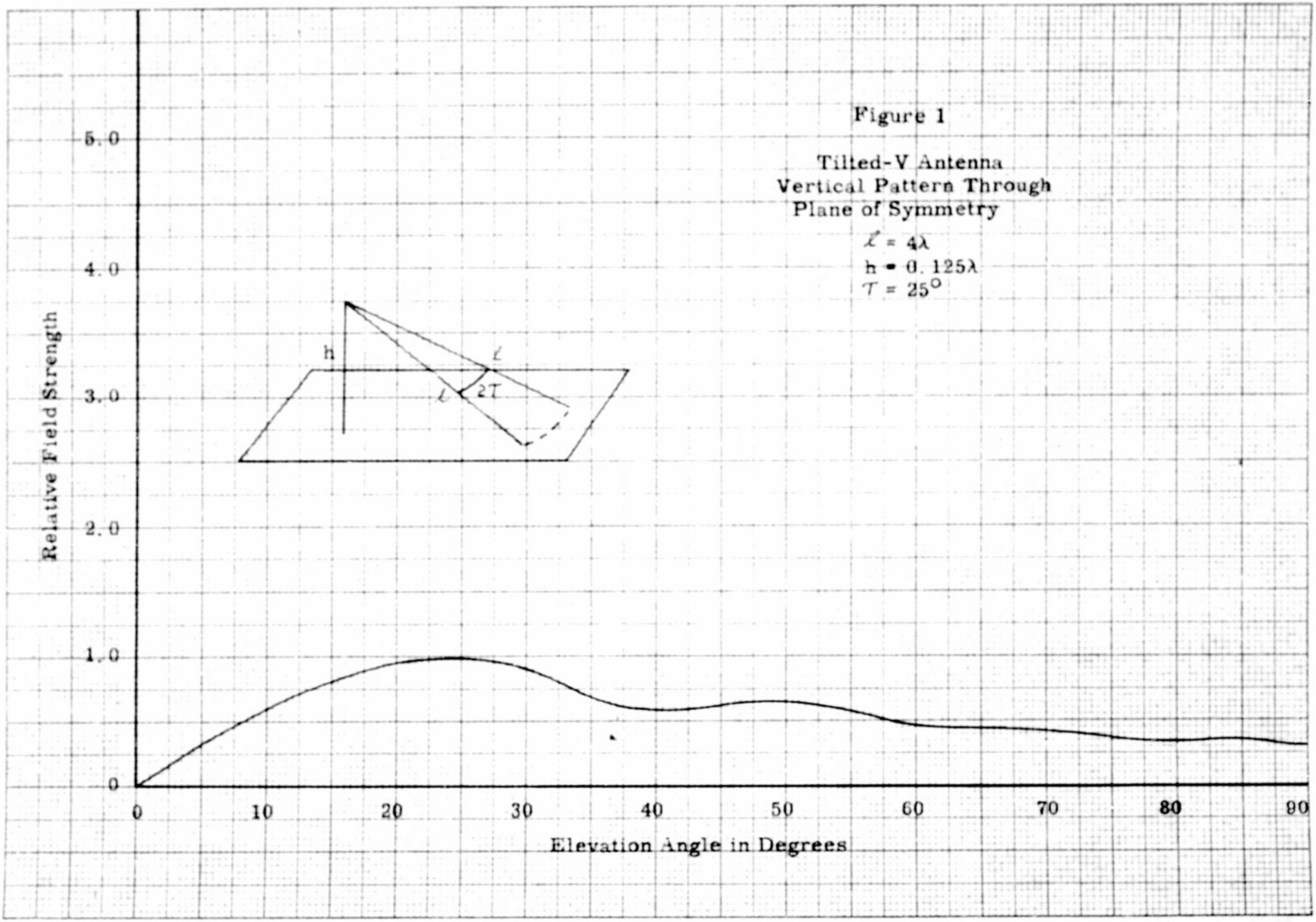


Figure 1

Tilted-V Antenna
Vertical Pattern Through
Plane of Symmetry

$\ell = 4\lambda$
$h = 0.125\lambda$
$\tau = 25^{\circ}$

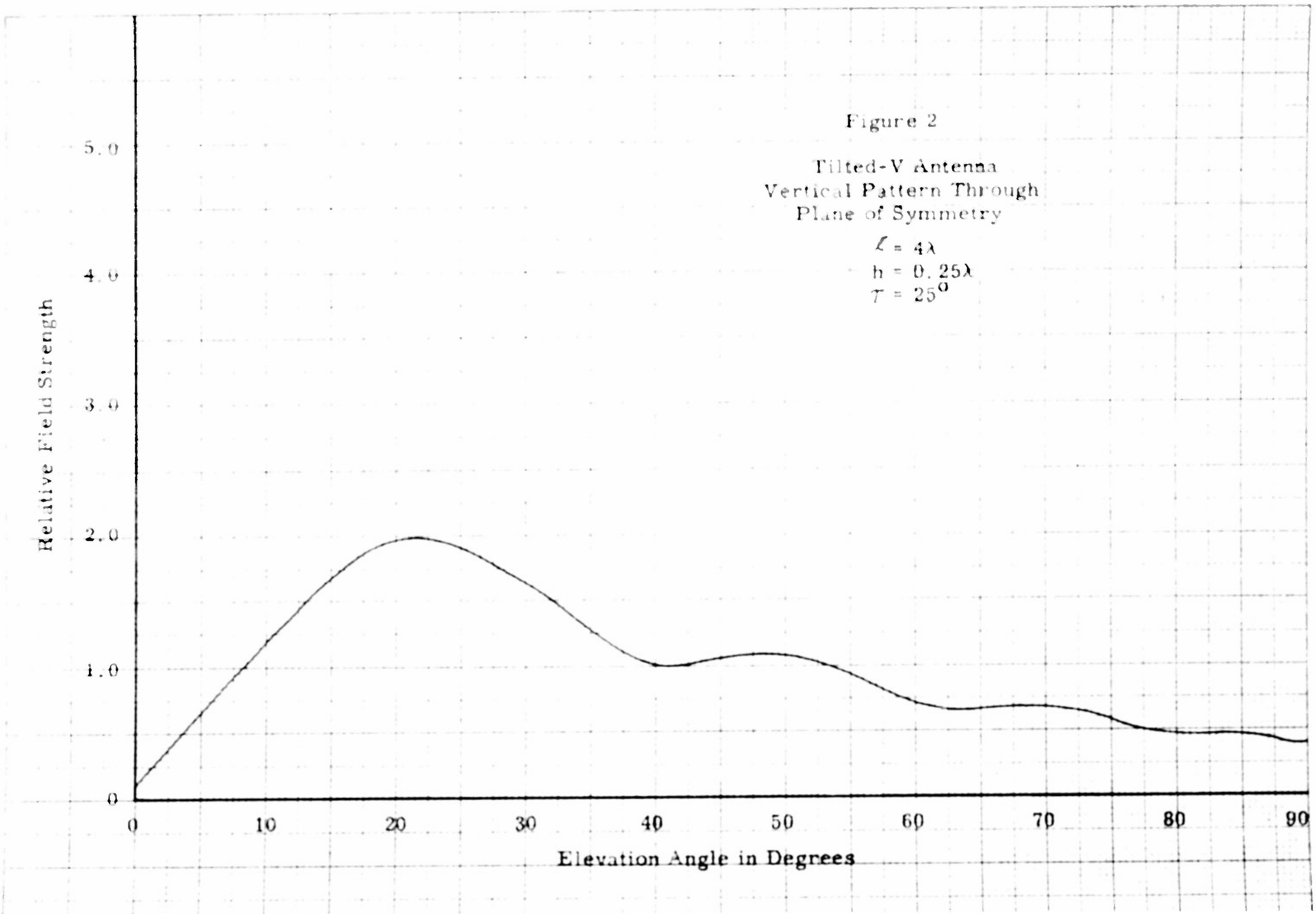


Figure 2

Tilted-V Antenna
Vertical Pattern Through
Plane of Symmetry

$\ell = 4\lambda$
$h = 0.25\lambda$
$\tau = 25^{\circ}$

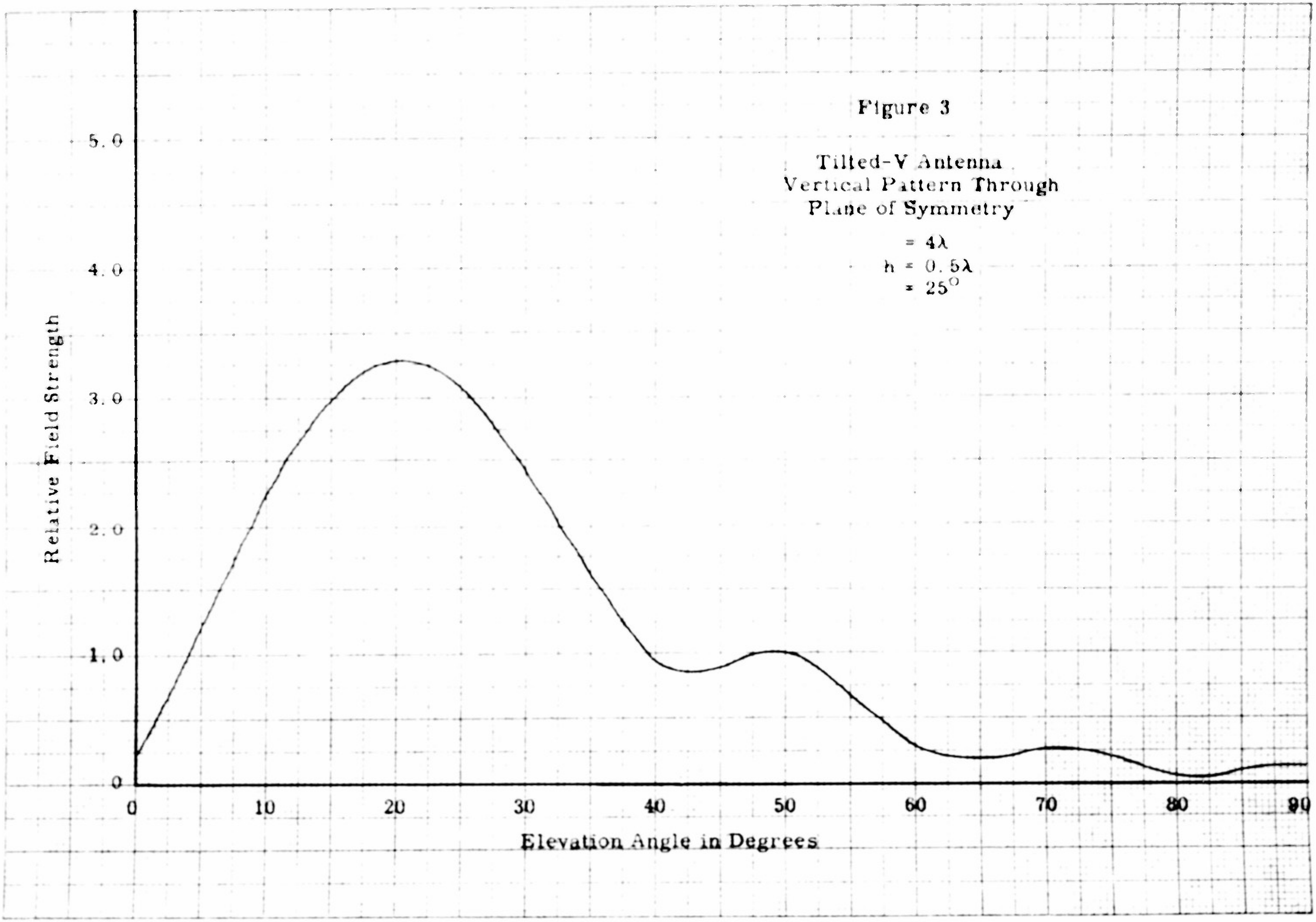


Figure 3

Tilted-V Antenna
Vertical Pattern Through
Plane of Symmetry

= 4λ
h = 0.5λ
= 25°

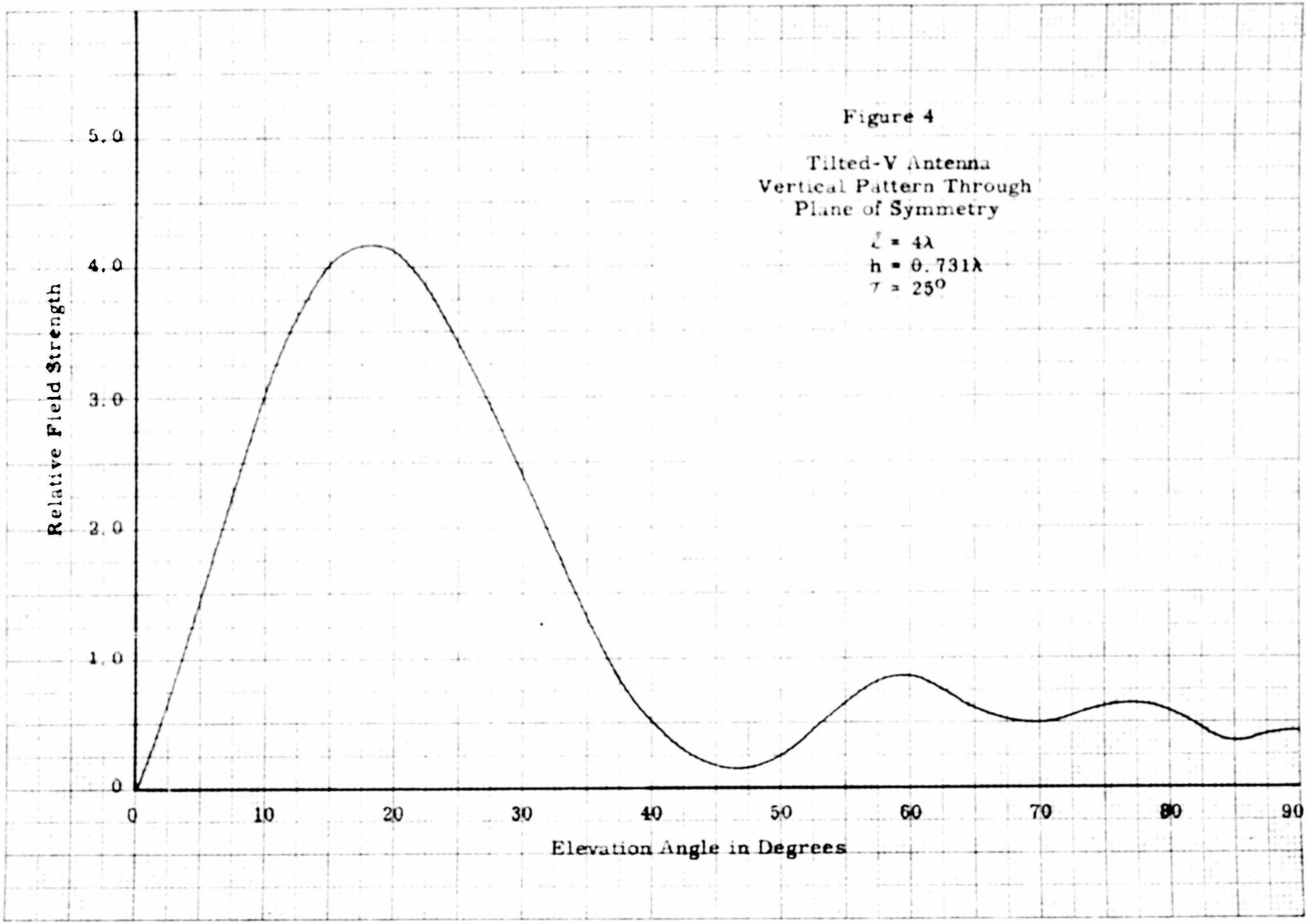


Figure 4

Tilted-V Antenna
Vertical Pattern Through
Plane of Symmetry

$\ell = 4\lambda$
$h = 0.731\lambda$
$\gamma = 25^{o}$

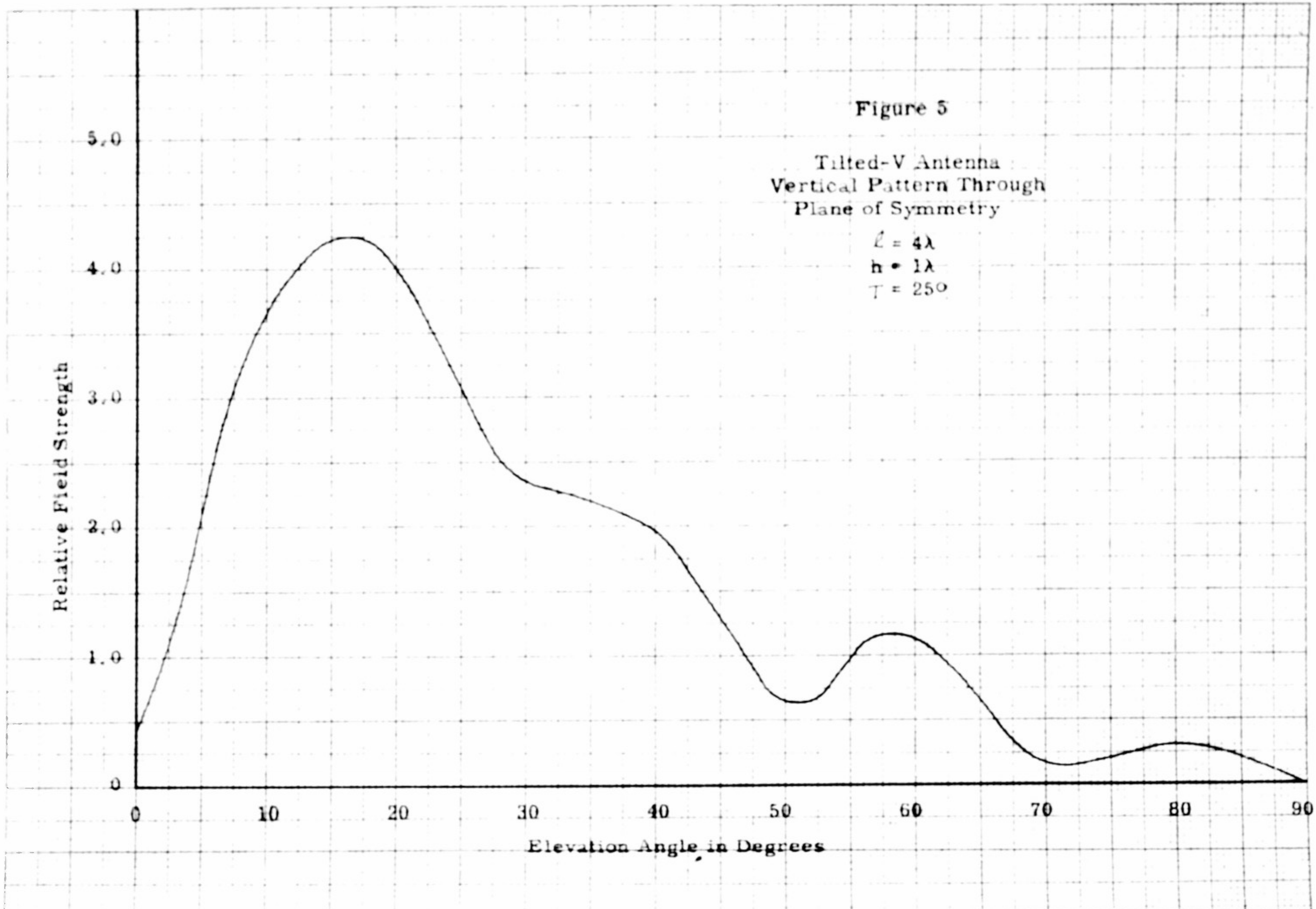


Figure 5

Tilted-V Antenna
Vertical Pattern Through
Plane of Symmetry

$\ell = 4\lambda$
$h = 1\lambda$
$T = 25^{\circ}$

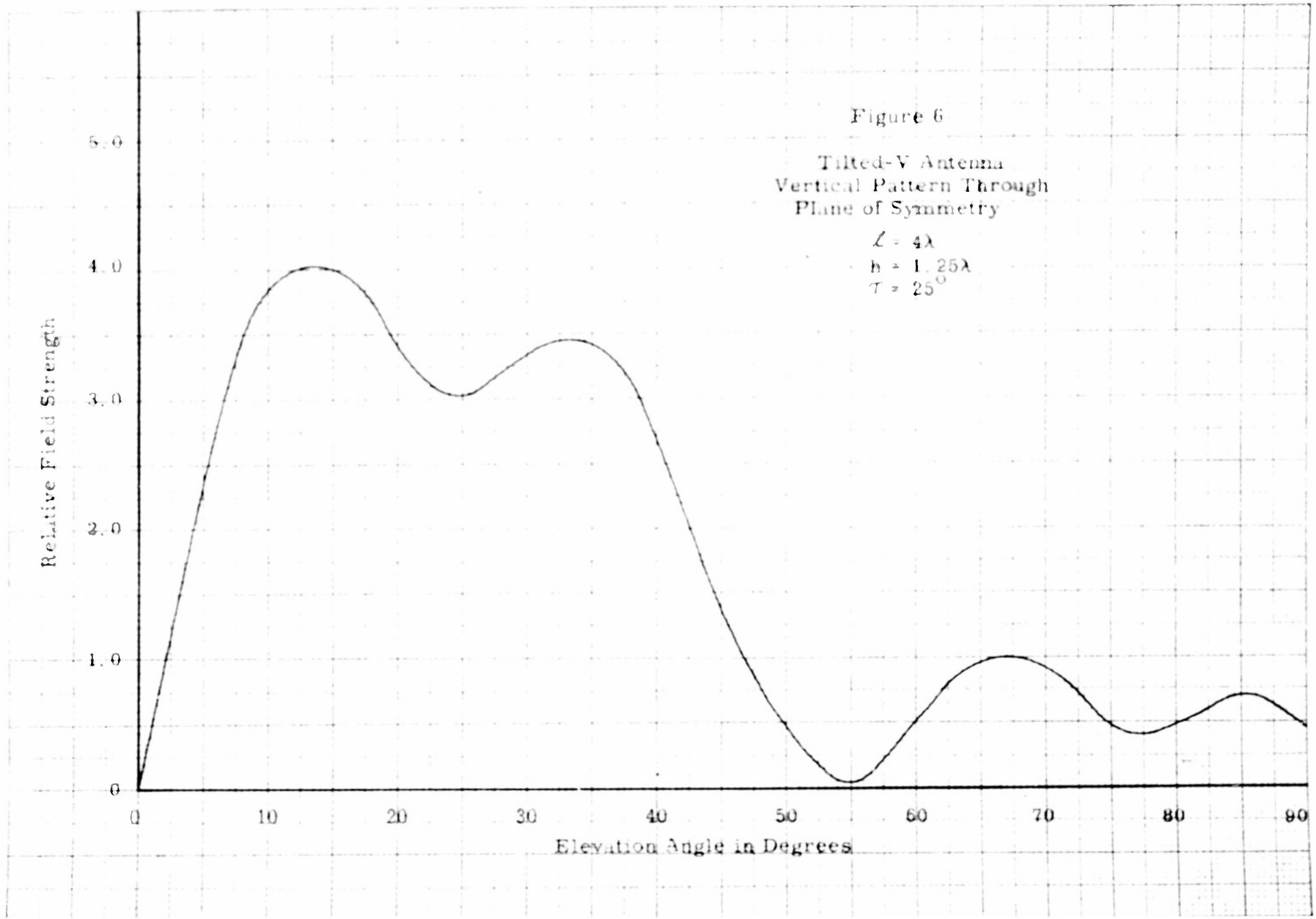


Figure 6

Tilted-V Antenna
Vertical Pattern Through
Plane of Symmetry

$\ell = 4\lambda$
$h = 1.25\lambda$
$\tau = 25^{\circ}$

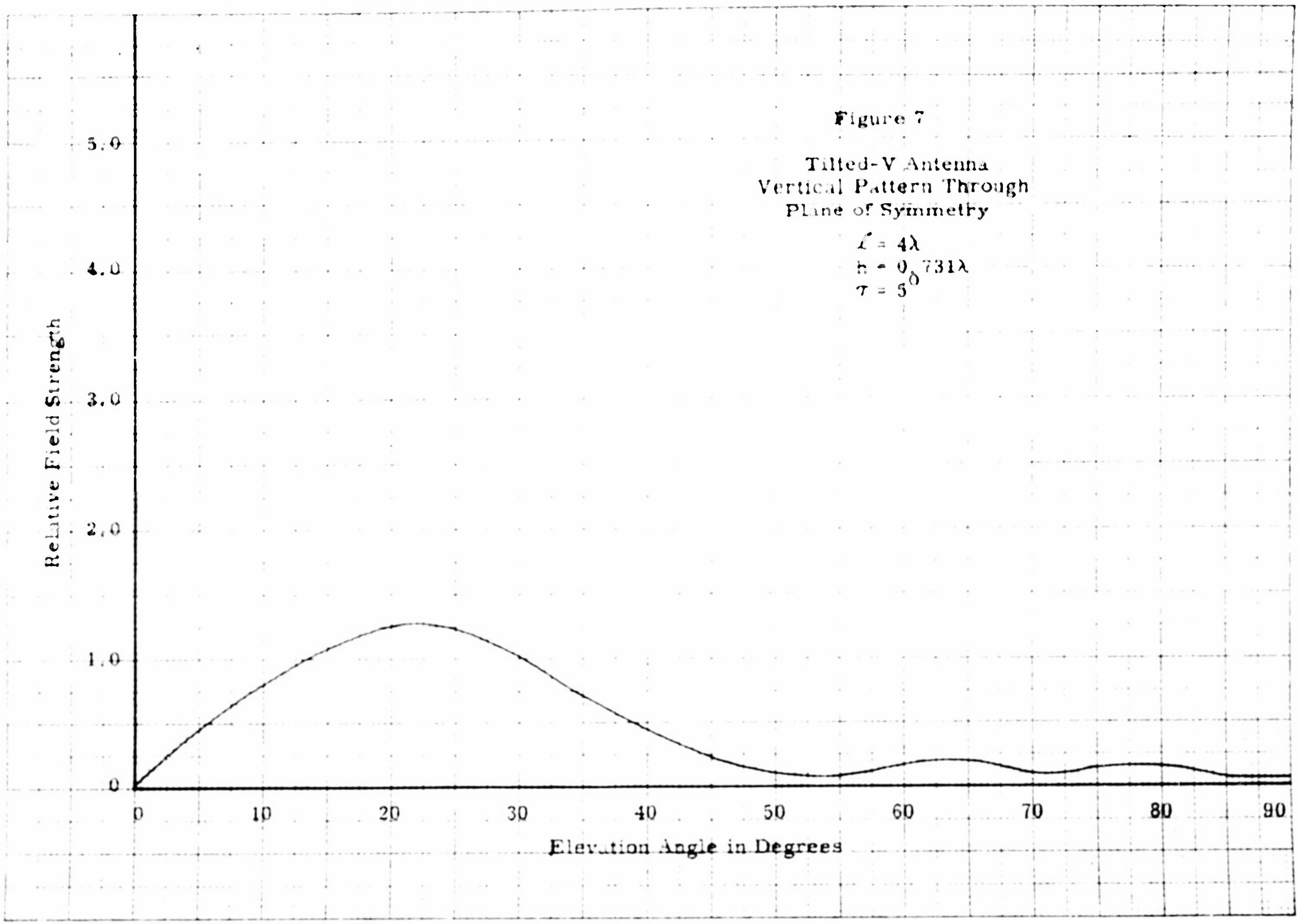


Figure 7

Tilted-V Antenna
Vertical Pattern Through
Plane of Symmetry

$\ell = 4\lambda$

$h = 0.731\lambda$

$\tau = 5^0$

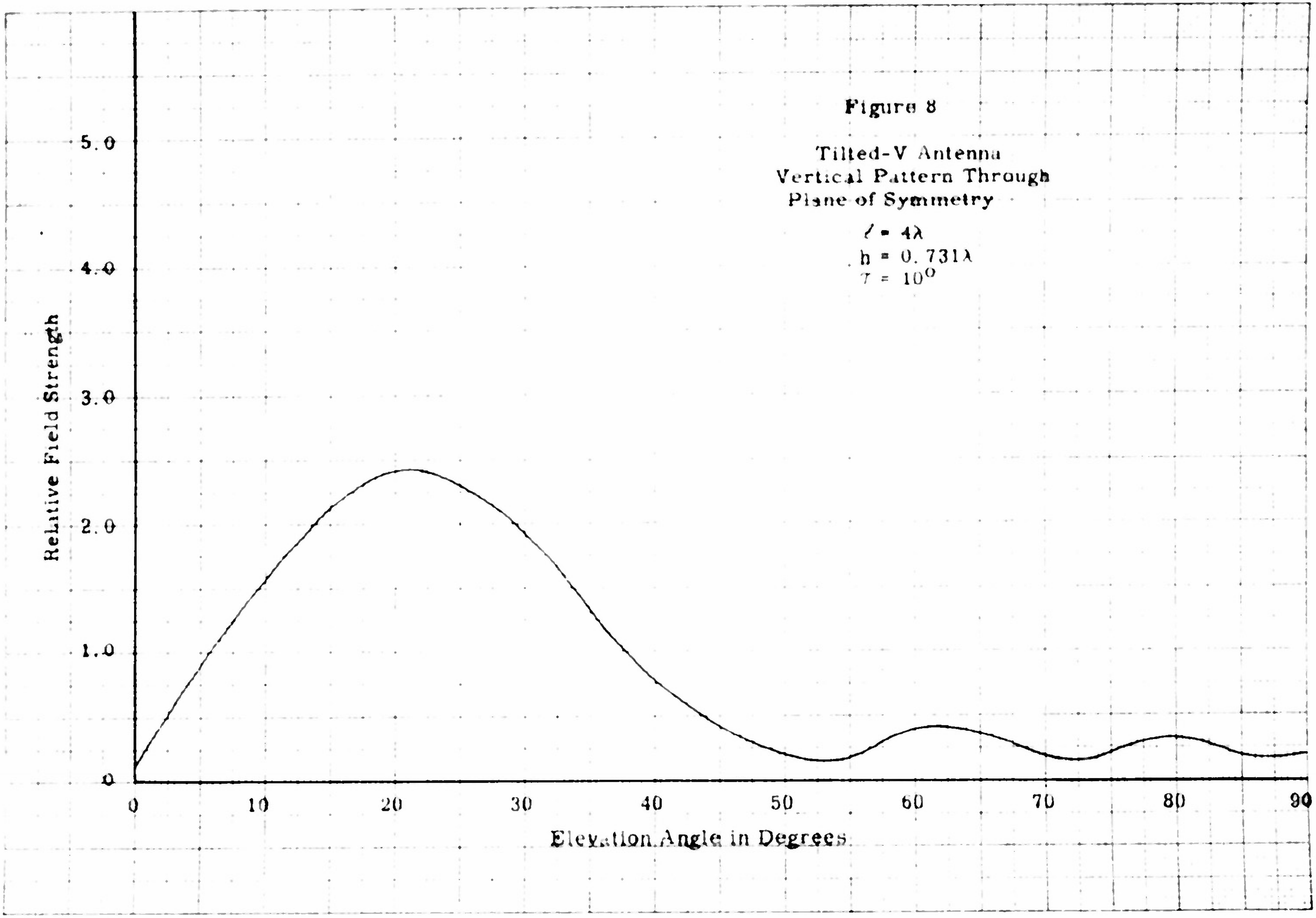


Figure 8

Tilted-V Antenna
Vertical Pattern Through
Plane of Symmetry

$\ell = 4\lambda$
$h = 0.731\lambda$
$\tau = 10^{\circ}$

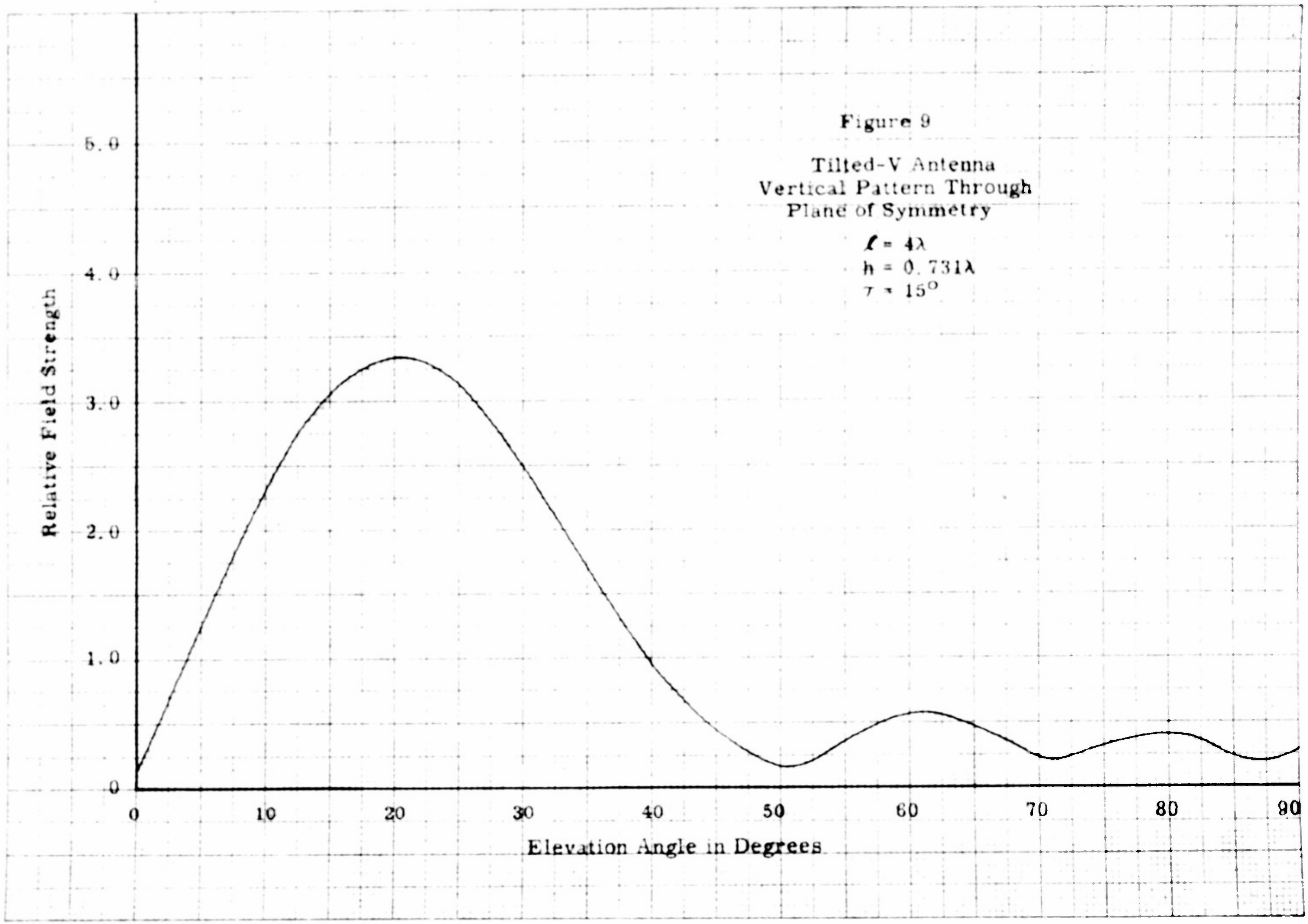


Figure 9

Tilted-V Antenna
Vertical Pattern Through
Plane of Symmetry

$\ell = 4\lambda$
$h = 0.731\lambda$
$\tau = 15^{\circ}$

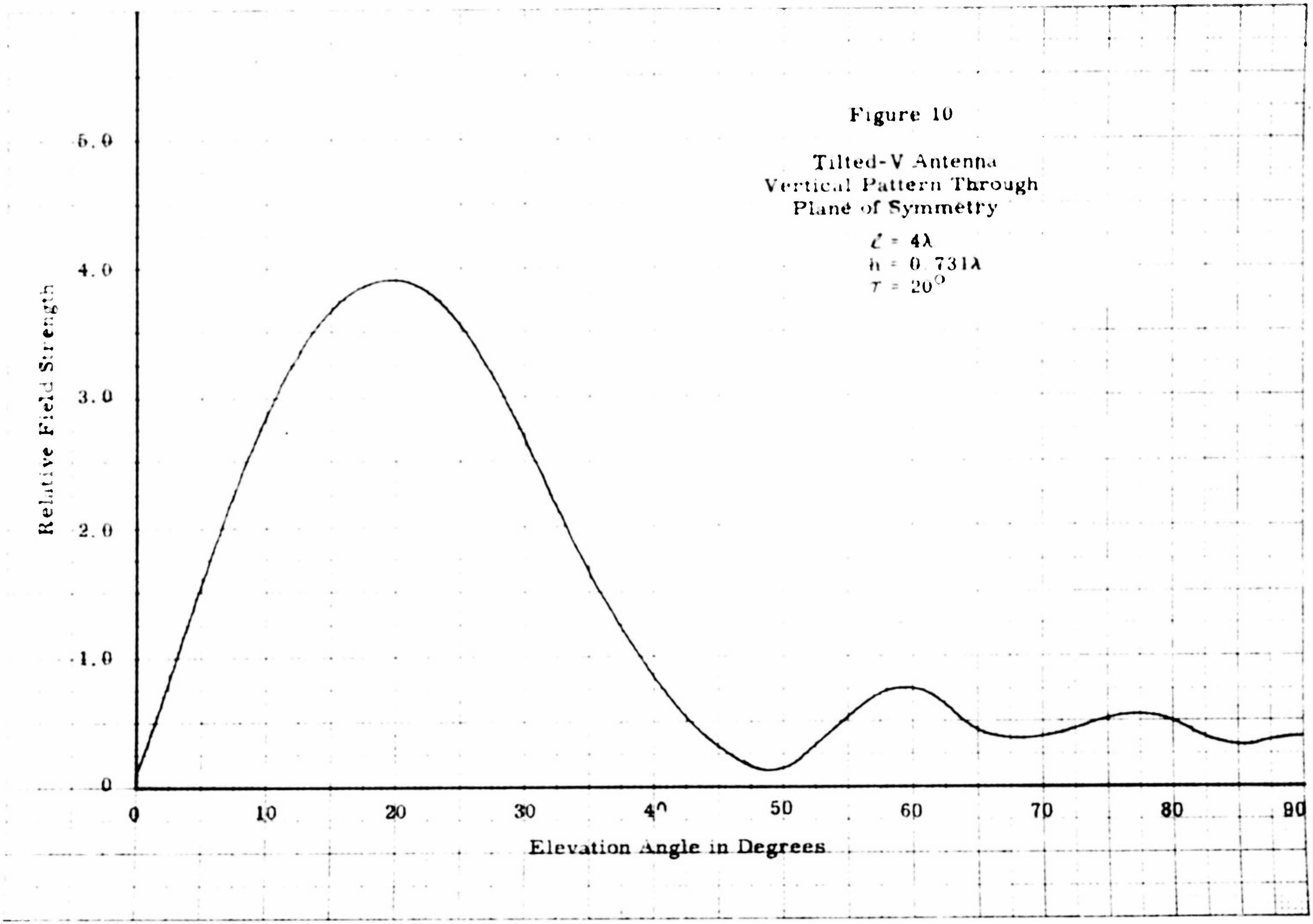


Figure 10

Tilted-V Antenna
Vertical Pattern Through
Plane of Symmetry

$\ell = 4\lambda$
$h = 0.731\lambda$
$\tau = 20^{\circ}$

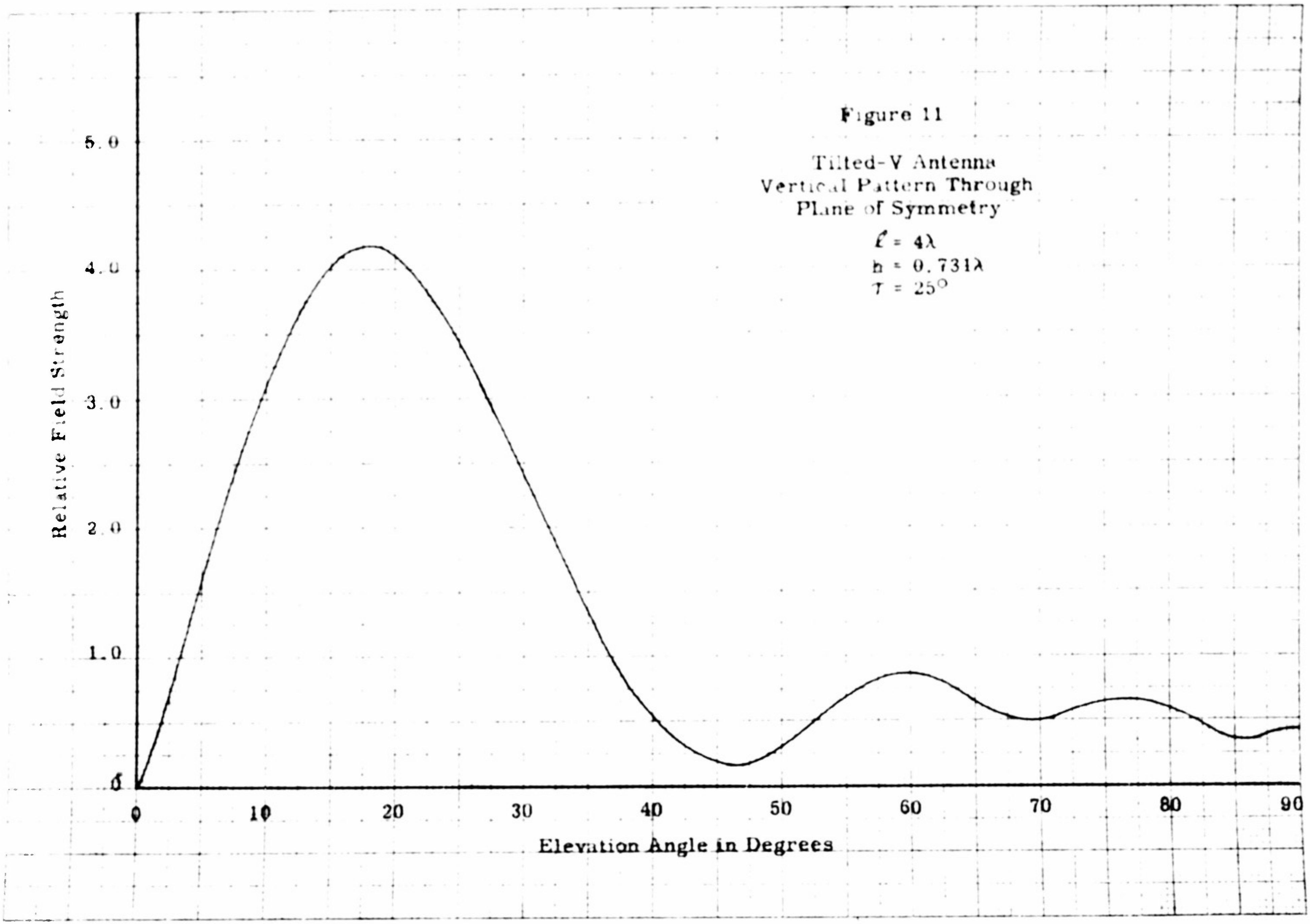


Figure 11

Tilted-V Antenna
Vertical Pattern Through
Plane of Symmetry

$\ell = 4\lambda$
$h = 0.731\lambda$
$\tau = 25°$

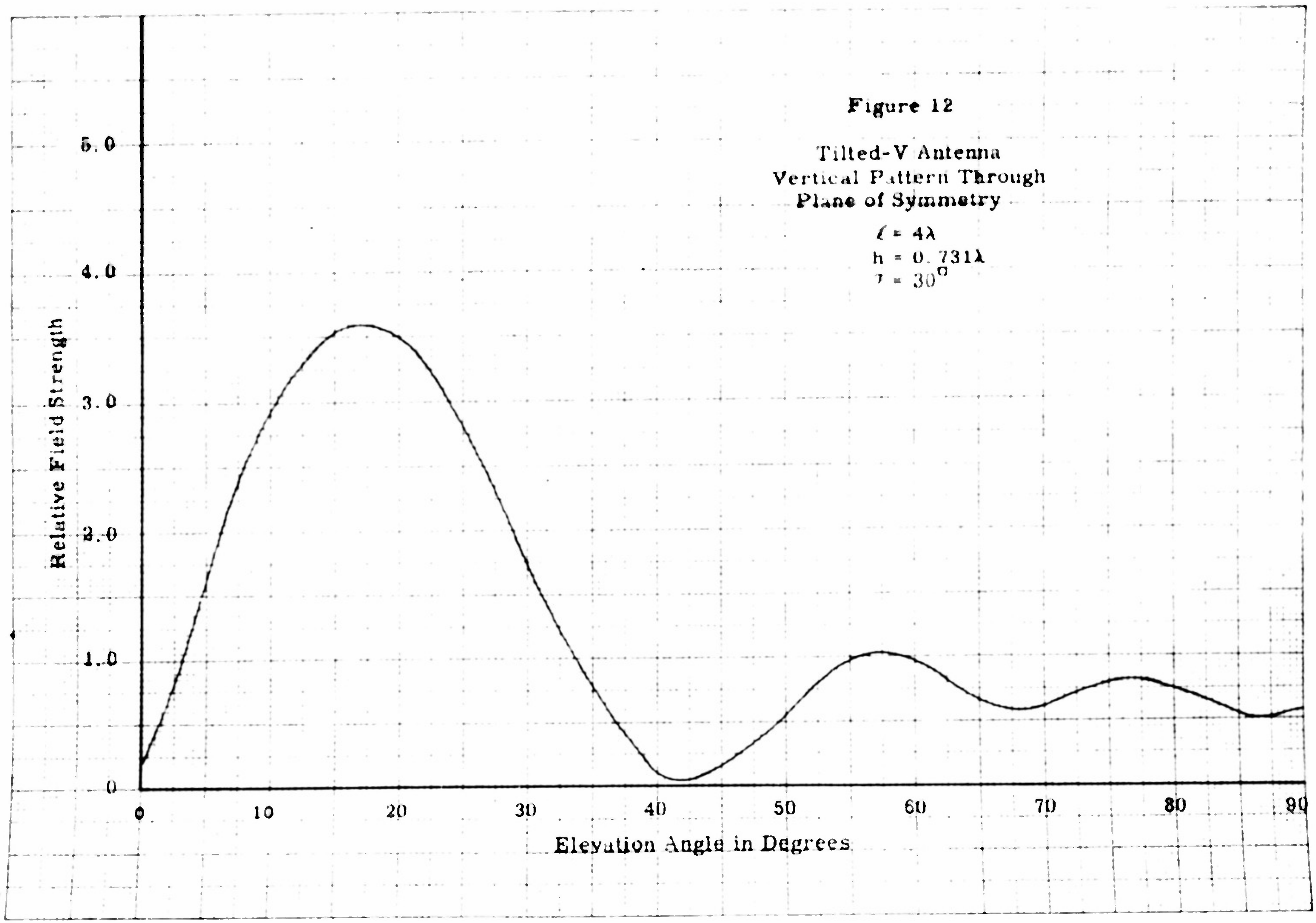


Figure 12

Tilted-V Antenna
Vertical Pattern Through
Plane of Symmetry

$\ell = 4\lambda$
$h = 0.731\lambda$
$\gamma = 30^\circ$

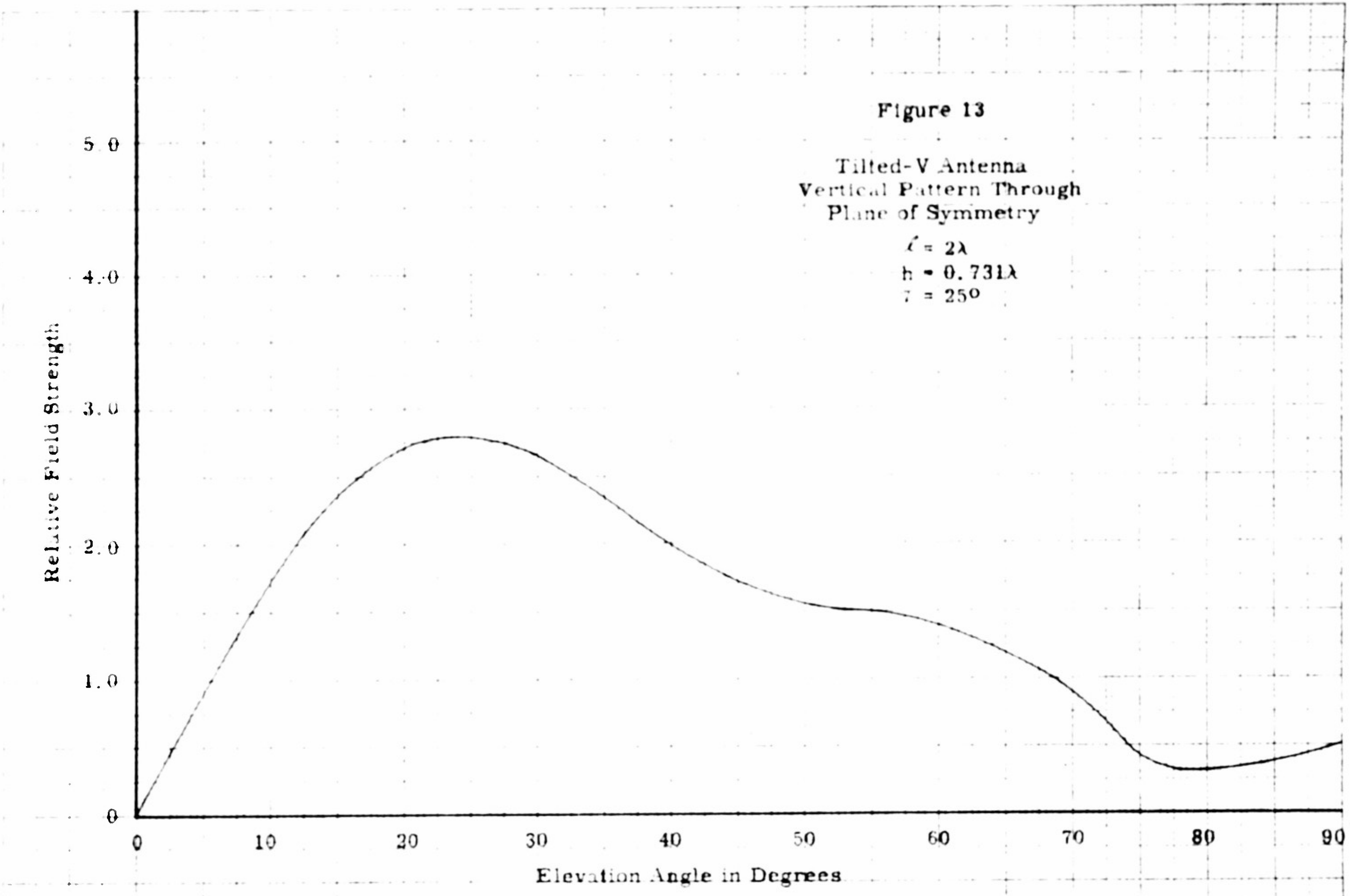


Figure 13
Tilted-V Antenna
Vertical Pattern Through
Plane of Symmetry
$\ell = 2\lambda$
$h = 0.731\lambda$
$\gamma = 25^{\circ}$
5.0
4.0
3.0
2.0
1.0
0
Relative Field Strength
0
10
20
30
40
50
60
70
80
90
Elevation Angle in Degrees

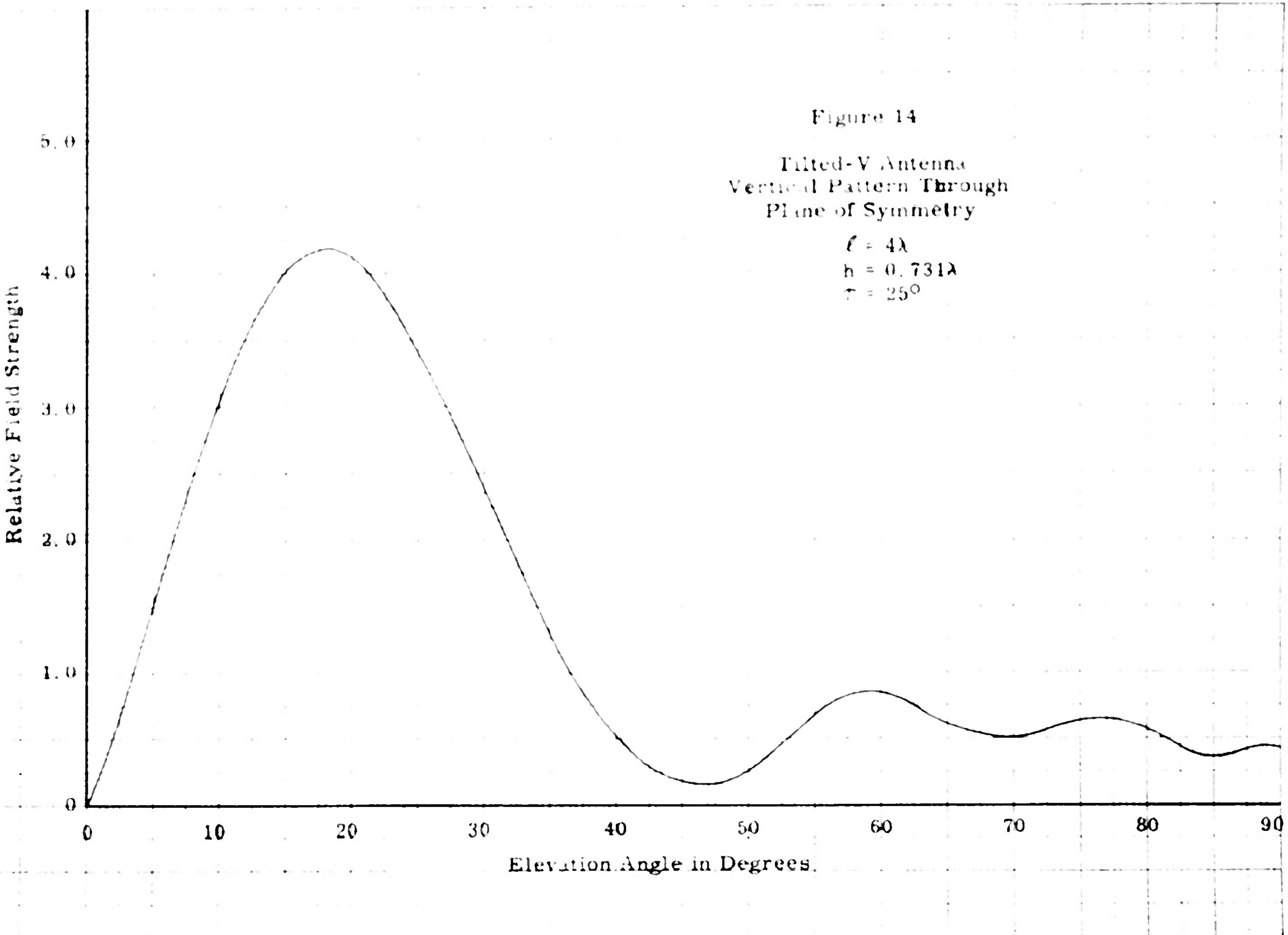


Figure 14

Tilted-V Antenna
Vertical Pattern Through
Plane of Symmetry

$\ell = 4\lambda$
$h = 0.731\lambda$
$\tau = 25^{\circ}$

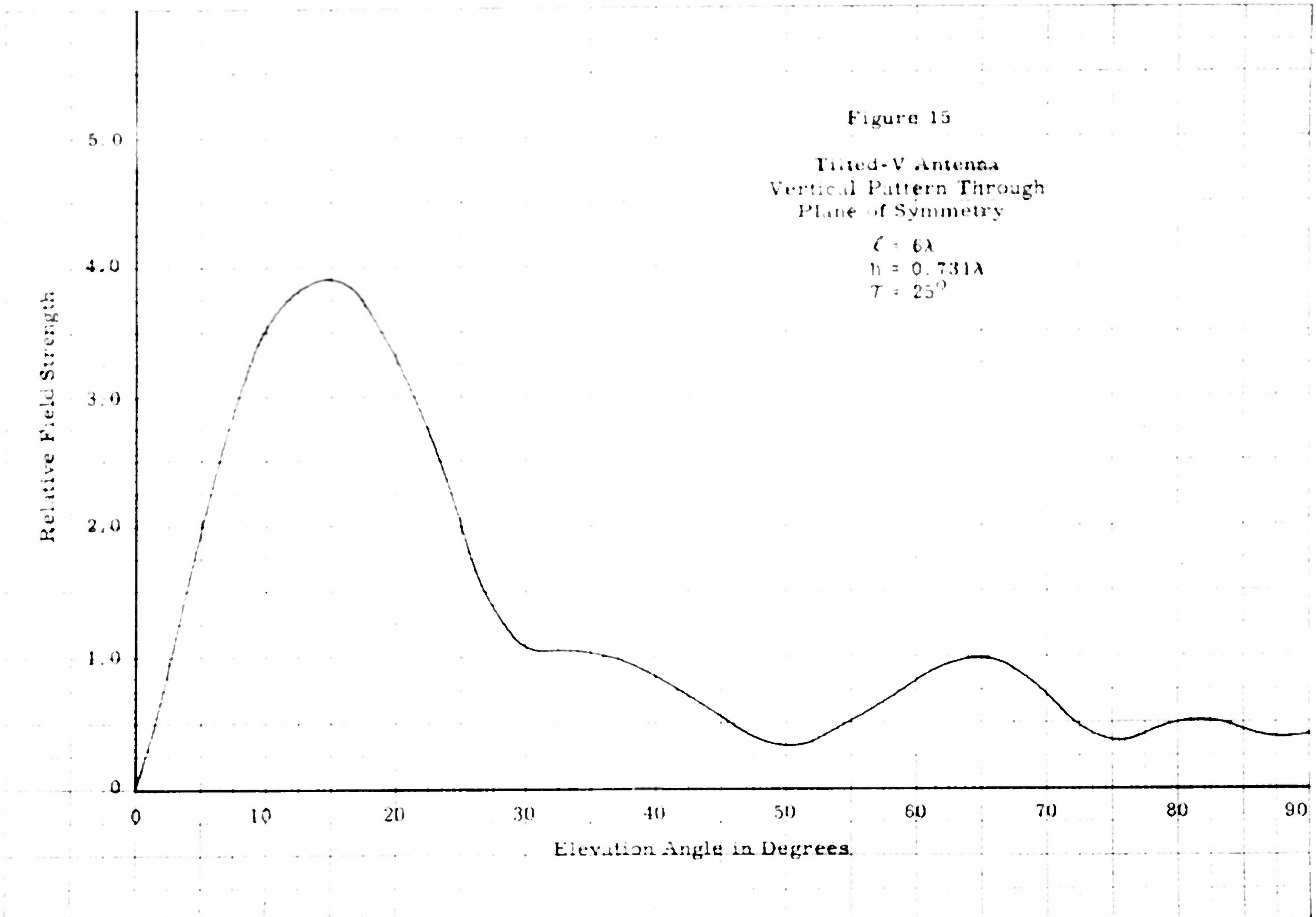


Figure 15

Tilted-V Antenna
Vertical Pattern Through
Plane of Symmetry

$\ell = 6\lambda$
$h = 0.731\lambda$
$T = 25^{0}$

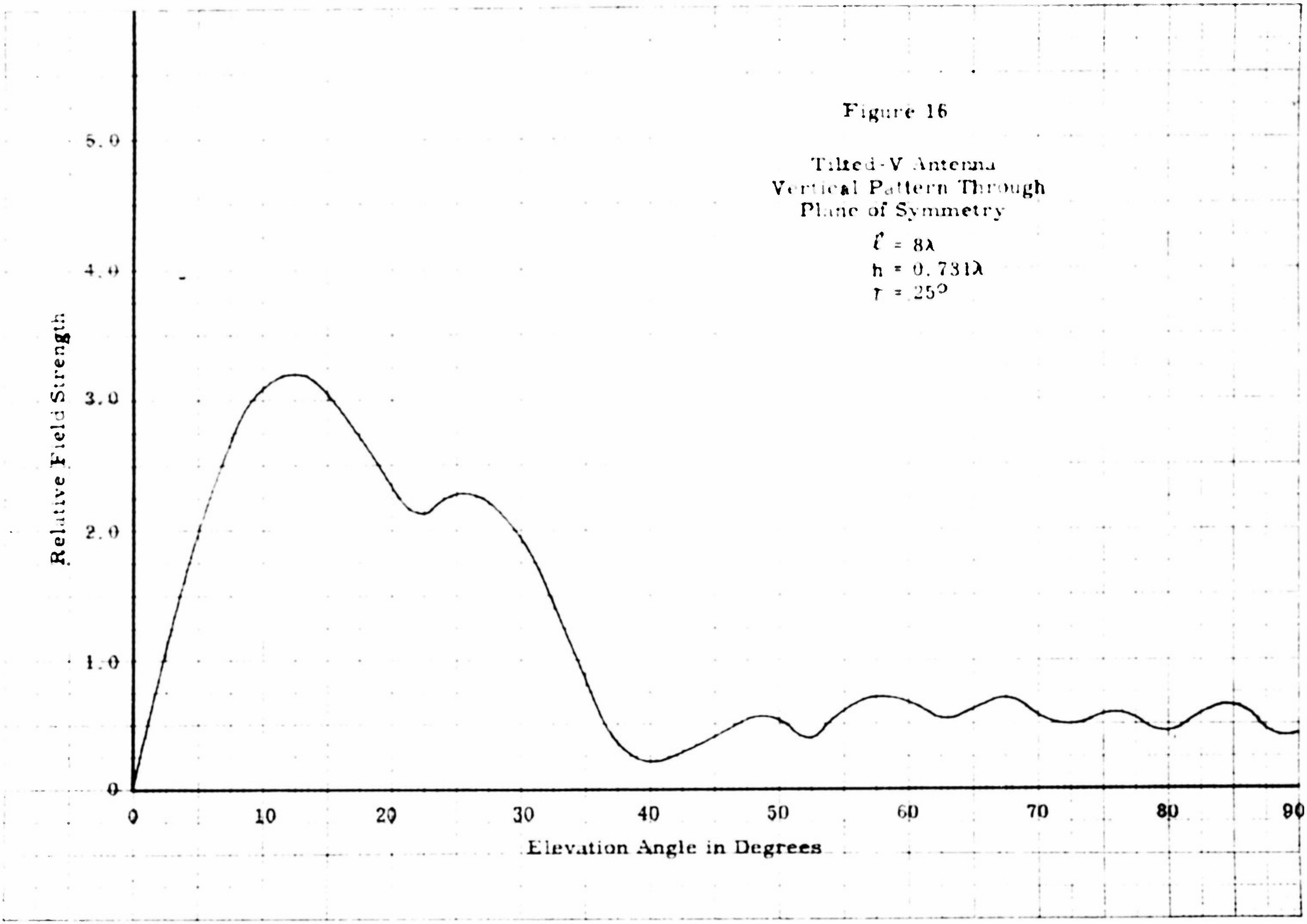


Figure 16
Tilted-V Antenna
Vertical Pattern Through
Plane of Symmetry
$\ell = 8\lambda$
$h = 0.731\lambda$
$\tau = 25°$
Relative Field Strength
5.0
4.0
3.0
2.0
1.0
0
0
10
20
30
40
50
60
70
80
90
Elevation Angle in Degrees